Discussion on "THE RELATION OF PLANT PATHOLOGY TO GENETICS"

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From the *Report of the Imperial Botanical Conference*, London, July 1924

Cambridge

At the University Press

Printed in Great Britain

Reprinted from the *Report of the Imperial Botanical Conference*, London, July 1924

THE RELATION OF PLANT PATHOLOGY TO GENETICS

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All plants which have been cultivated for any considerable period of time exist in innumerable forms or varieties. One of the most striking differences between the varieties of any one crop plant lies in their varying susceptibility to specific diseases; one variety may be extremely liable to a certain malady and another may be completely immune to it. On the other hand the same variety of cultivated plant may differ in susceptibility to a specific disease from season to season or place to place, so that in such a variety the genetical factors determining susceptibility or resistance must be modifiable in expression by changes in environmental conditions. Susceptibility or resistance to disease may be due to a single genetical factor or to multiple factors. It has been shown with many crops that resistance to disease may be deliberately combined with other desirable characters such as high yield and good quality, although it is sometimes difficult to break asunder the linkages often existing between resistance to disease and certain undesirable characters.

One of the most interesting results of attempts to elucidate the inheritance of resistance and susceptibility to disease is the indication that in the hybrid derivatives there are sometimes forms which are more resistant and also more susceptible than the original parents. On the University Farm at Cambridge some of the F_2 derivatives of a cross between "Rivet" and a "Vulgare" form of wheat are extremely susceptible to ergot, whereas the "Vulgare" form is practically immune and "Rivet" only moderately susceptible to it.

It is clear therefore that one of the most effective means of combating plant diseases is by breeding disease-resistant varieties. Prevention is better than cure, and one ideal in crop production is to possess varieties which are not liable to disease of a serious nature.

With plants, resistance to disease is not usually of a clear-cut nature, the degree of resistance being modifiable by environmental factors, although, with wart disease of potatoes, an immune variety appears to

be immune under all conditions. It is important to realise the amount of modification in disease-resistance that can be induced by changes in environment whether of soil or weather. In fact the increase in susceptibility is sometimes so considerable that it almost seems as if the genetical factors for resistance had been obliterated. Thus last season the variety of apple, Bramley Seedling, which is usually free from attacks of the scab fungus, was badly infested by this disease. Although the genetical factors for resistance may thus be exceptionally masked they still exist, and over a period of years will confer a weighty advantage upon varieties possessing them over varieties in which these factors are absent.

A valuable line of enquiry is to try to determine in what way changes of environment modify susceptibility to disease. The physiology of the crop plant may be considerably influenced by alterations in environment and a change of this nature may assist the development of the parasite, but the precise alterations may be difficult to elucidate, especially where the influence of soil condition is paramount. The physiology of the parasite also may be influenced in the direction of increasing its ability to attack the host. A part of the increased susceptibility under changed conditions may be due merely to greater physical opportunity for the parasite to cause infection. For instance, with leaf parasites it is essential that comparatively moist conditions should prevail in order to allow of infection. Again, with many parasitic fungi certain conditions of temperature within the range tolerated by the host may either greatly facilitate infection or entirely prevent it.

It is admitted that the genetical constitution both of the host and of the parasite may alter with the lapse of time, but mutations probably occur only rarely. The plant breeder can undoubtedly work faster in producing new desirable types of crop plants than genetical changes in either host or parasite are likely to occur. One of the most striking features of the work of Stakman and his colleagues in America in elucidating the various biologic forms of *Puccinia graminis* is the remarkable constancy of these types in infective capacity, so that fears of sudden changes in violence and range of infection by such parasites are probably unfounded.

Crop plants resistant to disease are usually obtained either by the deliberate combinations of the plant breeder or by the selection of resistant individuals in a mixed population. Both methods have been adopted with success, especially in dealing with annual crops such as cereals and cotton. To be economically profitable these new types must

have been subjected to rigorous tests as regards disease-resistance over a period of years, so that the average measure of resistance can be gauged. It is of the utmost importance in these tests that abundant opportunity for infection should be provided. For instance, in testing the resistance of barley to *Helminthosporium graminum* every opportunity should be afforded by copious provision of spores for all derivatives of the cross to be exposed to infection, otherwise plants which may remain free from attack may be looked upon mistakenly as immune or resistant when in reality they have only escaped infection through lack of infectious material.

It is generally recognised that resistance to one disease does not imply resistance to other diseases, although occasionally varieties of crop plants arise which remain free from attack by more than one serious disease. Again, owing to the existence of various biological strains of parasitic organisms and to profound environmental differences it is now realised that the problem of obtaining disease-resistant varieties is one which is specific almost to each country. It is a vain hope that in plant-breeding institutions in this country types of crop plants may be produced which will be available for commercial use in other parts of the Empire. For example, it is almost useless to attempt to obtain varieties of wheat in this country resistant to *Puccinia graminis*, which is the chief curse of wheat growing in Canada, Australia and East Africa, simply because the strain of the fungus which occurs on wheat is exceedingly rare in this country, so that an adequate test of resistance cannot be provided. It is important that a decision should be come to in each country as to what are the most important diseases of crop plants, and for the attention of the plant breeders to be concentrated upon these.

With perennial plants the problem of creating resistant types is more difficult, largely because of the longer time taken to achieve results. On the other hand the problem is of even greater importance than with annual crops because of the long period over which a perennial plant is productive. The devastation of the Weymouth pine by *Cronartium ribicola* and of the American chestnut by *Endothia parasitica* need only be recalled to realise the destruction that can be occasioned by fungi which attack trees. With the former disease there does not seem to be any hope of amelioration by the plant breeder, as not only is the Weymouth pine but other five-needled pines are attacked. With *Endothia parasitica* a closely related species of chestnut has been found to be markedly resistant to the disease. It is, however, in connection with fruit culture that results of great importance in the near future may be

expected by the combination of the characters of disease-resistance and other desirable qualities. If for instance the resistance to silver-leaf disease of the Pershore plum could be combined with the quality of the Victoria or Czar, fruit growers would be relieved from a constant menace. With apples too there is an immense field for the plant breeder. Some of the best varieties as regards productivity and quality are seriously attacked by canker and scab, both of which diseases are difficult to control by the usual methods of plant pathology, and it is to be hoped that in the process of time these troubles will be practically eliminated by the creation of new varieties. In this connection Salmon's work on hops leading to the creation of commercial types resistant to mildew is of great value.

It is with cereals that the most important work has been done hitherto in the production of disease-resistant varieties, following upon the demonstration by Biffen that susceptibility and resistance to yellow rust (*Puccinia glumarum*) of wheat were inherited according to Mendel's law. By following up this discovery an increase in cropping capacity has been obtained by the creation of such varieties as Little Joss and Yeoman. The only other wheat rust widely prevalent in this country is *Puccinia triticina*, the brown rust, but as this usually only occurs here in quantity during the later part of the growth of the wheat plant it probably has no material influence upon the yield of grain. In the Argentine, however, brown rust of wheat does serious damage, and it is of interest to know that Backhouse has recently found that a Chinese variety of *Triticum vulgare* is extremely resistant to this rust, thus giving hope that new combinations can be effected which will greatly surpass the old forms in use in that country. In countries where *Puccinia graminis*, the black rust, is prevalent the position is much more serious. As is well known, this fungus in attacking chiefly the stem has a much more serious influence upon the crop than the brown and yellow rusts, and it is by no means unknown for more than 50 % of the crop in North America and other wheat-producing countries to be lost by its ravages. In North America the production of resistant types is complicated, as Stakman has shown, by the presence of many different biologic forms of *Puccinia graminis*. Some of these biologic forms occur in different areas, so to this extent the problem of breeding resistant types will be specific to those areas, unless varieties can be gradually built up which are resistant to most of the forms of black rust. It has been shown that the factor for resistance in some varieties is the same for several different forms of the rust. For instance, the variety Kanred is practically immune to at least eleven

different forms of *Puccinia graminis*. Little is yet known about the resistance of varieties of cereals to smut fungi, although the losses occasioned by them in some countries are not less severe than those caused by rusts. Bunt is a very serious disease of wheat in many parts of the world, especially in winter-hardy varieties, and it is greatly to be desired that commercial varieties should be introduced which are more resistant than the present types. Steeping or sprinkling the grain with a fungicide is an efficient protection against this disease in most countries, but in some parts, *e.g.* the Pacific States of North America, infection is liable to occur through the soil. Gaines[1] has shown that resistance to bunt is a segregating character so that there is hope of achievement along genetical lines as regards this disease. Perhaps the most serious disease of barley is *Helminthosporium graminum*, the cause of heavy mortality of young plants and blindness of the ears, but little is yet known as to the comparative susceptibility of varieties. Work is in progress at Cambridge to try to determine this and to ascertain whether resistant types can be built up along Mendelian lines.

With other herbaceous crop plants work is proceeding in many parts of the world to discover or to create types which are resistant to some of the most troublesome diseases. In connection with this work important results are being obtained as to the nature of disease-resistance and as to the manner in which the factors for resistance are coupled with other characters. For instance, Fromme and Wingard[2] have shown that with *Phaseolus vulgaris* all varieties with red or mottled seed are resistant to attacks by the rust fungus *Uromyces appendiculatus*, while white varieties are specially susceptible. Another biologic strain of this fungus attacks the cow pea (*Vigna lutea*) both in America and in Egypt, and in the latter country[3] a type of this plant has recently been isolated by selection and propagated on a large scale, which seems to be almost completely immune. Another interesting correlation between the presence of pigment and resistance to disease has recently been demonstrated by Walker[4] in the case of onions in America. He finds that with the disease of onion called "smudge," caused by *Colletotrichum circinans*, coloured varieties are highly resistant and white varieties are susceptible. The pigment in the coloured varieties is chiefly present in the outer

[1] Gaines, E. F. "Genetics of Bunt Resistance in Wheat," *Journ. Agric. Res.* p. 445, 1923.

[2] Fromme, F. D. and Wingard, S. A. "Varietal Susceptibility of Beans to Rust," *Journ. Agric. Res.* p. 385, 1921.

[3] Hefnawi, M. T. "On the selection of a rust-immune variety of *Vigna sinensis*," *Mem. of Agric.*, Hortic. Sect., Egypt, 1919.

[4] Walker, J. C. "Disease resistance to onion smudge," *Journ. Agric. Res.* p. 1019, 1923.

scales, and when these are removed the inner fleshy scales of these varieties are found to be susceptible. Furthermore, Walker has shown that a substance associated or identical with the pigment has a very detrimental influence on the growth of the fungus and is unquestionably bound up with the resistance of these varieties.

Perhaps the most difficult class of diseases to be dealt with by the ordinary methods of plant pathology are those which enter through the root systems and which frequently cause wilting. Soil sterilisation is employed on a considerable scale in greenhouse cultivation to deal with diseases of this class, but it is obvious that this is out of the question on a field scale, and it is equally clear that the production of resistant varieties would be a far better and cheaper means of control. Much work has been done in America in introducing varieties of herbaceous crop plants which are resistant to wilt diseases. In California for instance some varieties of tomatoes remarkably resistant to the wilt caused by *Fusarium lycopersici* are stated by Shapovalov and Lesley[1] to have been produced by breeding. At present in this country considerable damage is being done by a wilt disease of carnations where these are grown on a large scale under glass. This disease, caused by *Fusarium dianthi*, is particularly troublesome to deal with, but as with most cultivated plants, there are great varietal differences in susceptibility. These differences are of such a character as to afford a sufficient basis on which to build up by breeding a wide range of resistant types.

It may be argued, from the considerations put forward above, that in the process of time the measures devised by plant pathologists for the control of disease will give place entirely to the ameliorative measures of geneticists. To abolish disease by the elimination of susceptible varieties is, however, a counsel of perfection, and is never likely to be achieved in practice. As has already been pointed out, changes in environmental conditions sometimes exercise a profound influence upon the incidence of disease in some classes of plants ordinarily resistant, and again the pathogenicity of micro-organisms is probably liable to modification over long periods of time. The best outlook for the future is for the plant pathologist and geneticist to work in co-operation with each other in the production of disease-resistant types, and for the plant pathologist to perfect his methods for dealing with disease in susceptible varieties by means of plant sanitation, soil sterilisation, the application of fungicides, and, above all, by a careful study of the environmental conditions

[1] Shapovalov and Lesley, J. W. "Behaviour of certain varieties of tomatoes towards *Fusarium*-wilt infection in California," *Phytopathology*, p. 188, 1924.

under which crop plants are least liable to disease. Frontal attacks upon fungus diseases of crop plants are usually futile, and in general these troublesome organisms can usually be defeated only by the application of subtler methods.